ASTRONOMICAL PHENOMENA FOR THE WEEK 1886 *MAY* 2-8

(FOR the reckoning of time the civil day, commencing at Greenwich mean midnight, counting the hours on to 24, is here employed.)

At Greenwich on May 2

Sun rises, 4h. 32m.; souths, 11h. 56m. 50·4s.; sets, 19h. 22m.; decl. on meridian, 15° 26′ N.: Sidereal Time at Sunset, 10h. 4m.

Moon (New on May 4) rises, 4h. 10m.; souths, 10h. 42m.; sets, 17h. 25m.; decl. on meridian, 5° 29′ N.

Planet	Rises h. m.	Souths h. m.	Sets h. m.	Decl. on meridian ° ′
Mercury	4 0	10 23	16 46	3 50 N.
Venus	3 13	9 5	14 57	2 18 S.
Mars	12 59	19 57	2 55*	10 39 N.
Jupiter	14 49	21 7	3 25*	2 43 N.
Saturn	7 26	15 38	23 50	22 51 N.

* Indicates that the setting is that of the following morning.

Occultations of Stars by the Moon (visible at Greenwich)

May	Star	Mag.	Disap. h. m.	Reap. h. m.	Corresponding angles from vertex to right for inverted image ° °
6	111 Tauri	5½	20 12	21 3	114 324
6	117 Tauri	6	21 42	22 21	88 342

Saturn, May 2.—Outer major axis of outer ring = 39″·1; outer minor axis of outer ring = 17″·4; southern surface visible.

May	h.	
2	1	Mercury in conjunction with and 0° 6′ south of the Moon.
7	1	Mercury at greatest elongation from the Sun, 26° west.

Positions of the Comet Barnard (for Berlin Midnight)

May	R.A. h. m. s.	Decl. ° ′	Log. Δ	Brightness
2	1 38 8	40 28 N.	9·956	118
4	1 39 14	40 6	9·924	136
6	1 41 34	39 23	9·889	155

Variable-Stars

Star	R.A. h. m.	Decl. ° ′		h. m.
U Monocerotis	7 25·4	9 32 S.	May 6,	0 0 *M*
R Crateris	10 55·0	17 43 S.	,, 3,	0 0 *M*
δ Libræ	14 54·9	8 4 S.	,, 2,	3 0 *m*
U Coronæ	15 13·6	32 4 N.	,, 6,	23 35 *m*
U Ophiuchi	17 10·8	1 20 N.	,, 5,	3 4 *m*
		and at intervals of		20 8
X Sagittarii	17 40·4	27 47 S.	May 5,	2 20 *m*
			,, 8,	0 0 *M*
U Sagittarii	18 25·2	19 12 S.	,, 2,	21 40 *m*
			,, 5,	21 35 *M*
β Lyræ	18 45·9	33 14 N.	,, 3,	2 25 *m*
η Aquilæ	19 46·7	0 7 N.	,, 7,	0 0 *M*

M signifies maximum; *m* minimum.

Meteor Showers

There are no showers of great importance visible during this week. Meteors from the following radiants have been observed in previous years:—From Crater, R.A. 170°, Decl. 10° S.; near α Ursæ Majoris, R.A. 170°, Decl. 62° N.; from Virgo, R.A. 202°, Decl. 9° N.; from Aquila, R.A. 290°, Decl. 10° N.; and one with radiant at R.A. 234°, Decl. 46° N.

Stars with Remarkable Spectra

Name of Star	R.A. 1886·0 h. m. s.	Decl. 1886·0 ° ′	Type of spectrum
S Coronæ	15 16 45	31 46·7 N.	III.
τ^4 Serpentis	15 31 11	15 28·7 N.	III.
R Serpentis	15 45 26	15 28·8 N.	III.
367 Birmingham	15 59 41	47 33·1 N.	III.
47 Serpentis	16 2 58	8 50·3 N.	III.
371 Birmingham	16 3 7	8 55·1 N.	III.
δ Ophiuchi	16 8 22	3 23·9 S.	III.
V Ophiuchi	16 20 24	12 9·5 S.	IV.
α Scorpii	16 22 25	26 10·6 S.	III.
g Herculis	16 24 53	42 7·9 N.	III.
α Herculis	17 9 26	14 20·2 N.	III.

ON THE FORCES CONCERNED IN PRODUCING THE SOLAR DIURNAL INEQUALITIES OF TERRESTRIAL MAGNETISM [1]

IN an article on terrestrial magnetism in the present edition of the "Encyclopædia Britannica," I have endeavoured to show two things:—

(1) That of all the various hypotheses which have been started with the view of explaining the solar diurnal inequalities of terrestrial magnetism, the most probable is that which considers these inequalities to be caused by electric currents in the upper regions of the earth's atmosphere.

(2) That in the neighbourhood of the North Magnetic Pole (judging from observations discussed by Sabine) such currents have in all probability horizontal components flowing in from all sides towards that pole, so that on one side of the pole this component will have a direction the reverse to that which it has on the opposite side of the pole.

Dr. Schuster (see Report of Magnetical Committee of British Association) has deduced from this the legitimate inference that here we must have a vertical current or component of currents, inasmuch as without this we cannot imagine a series of strictly horizontal currents flowing in from the circumference to the centre like the spokes of a wheel.

I think it is desirable that this method of discussion should be extended to the phenomena round the magnetic equator. This magnetic equator may be regarded as approximately coincident with the terrestrial equator. It is the line all along which the freely suspended needle points horizontally, just as the magnetic pole is the place at which the freely suspended needle points vertically downwards.

Now a little to the north of the magnetic equator we have, broadly speaking, the following phenomena:—

(1) When the sun is north of the line, the influence of the sun upon the declination-needle (as represented by that oscillation which culminates an hour or two after noon) tends to drive the North Pole to the west. But when the sun is south of the line this action becomes reversed, and drives the North Pole eastwards.

(2) Whether the sun is north or south of the line, its action upon the bifilar needle (as represented by that oscillation which culminates about noon) tends to increase the horizontal force.

Now let us go a little to the south of the magnetic equator, and we find the following behaviour:—

(3) When the sun is south of the line, the influence upon the declination-needle represented as above tends to drive the North Pole to the east. But when the sun is north of the line this action becomes reversed, and the North Pole is driven westwards.

(4) Whether the sun is north or south of the line, its action upon the bifilar needle, represented as above, shows that it tends to increase the horizontal force.

It is, indeed, well known that there is a north-hemisphere and a south-hemisphere action of the sun upon the declination-needle, the one being the reverse of the other, and the southern limit of the first action being the northern limit of the second. And furthermore this boundary line oscillates backwards and forwards, so that, when the sun is in the north, a station near the equator, but north of it, exhibits a more distinctively northern character of oscillation, while, when the sun is in the south, it will exhibit a more or less southern character in its oscillation.

If we now venture to ascribe the actions represented in (1), (2), (3), and (4) to currents in the upper atmospheric regions, we shall have—

(1) when the sun is north, caused by a positive current going from south to north;

(2) caused by a positive current going from west to east;

(3) when the sun is south, caused by a positive current going from north to south;

(4) caused by a positive current going from west to east.

The resultant of (1) and (2) would be a horizontal positive current going in a direction not far from south-west, and the resultant of (3) and (4) a similar current going in a direction not far from north-west. The analogy in direction as well as oscillation to the two systems of anti-trades is at once apparent, and it will be strengthened if we reflect that, in the magnetical as well as the meteorological system, we must have a vertical current at the equator. This current might probably be repre-

[1] Being the substance of a Paper recently read before the Literary and Philosophical Society of Manchester, by Prof. Balfour Stewart, F.R.S.

sented by one carrying positive electricity down or negative electricity up, whereas that at the North Magnetic Pole might be one carrying positive electricity up or negative electricity down. We say *probably*, because it is exceedingly difficult to imagine that either of these vertical currents goes through the lower regions of the atmosphere into the earth, and it is likewise very difficult to imagine that the system of currents is an open one. They must, therefore, somehow close themselves in the upper atmospheric regions, and we may thus perhaps imagine that, while we have an ascending current at the North Magnetic Pole, we have a series of descending positive currents at the equator.

Or, if we prefer to render the analogy between the meteorological and magnetical systems more verbally complete, we should say ascending negative currents at the equator and descending negative currents at the pole.

These vertical currents being supposed to be confined to the upper regions of the atmosphere, we might imagine that they ought to render themselves visible at the magnetic pole, where they are most concentrated. If so, they would appear as a luminous vertical curtain or fringe suspended in mid-air. This at once suggests to us that the well-known form and nearly continuous appearance of the aurora in these regions may be due to this cause, and may represent to us the vertical component of those currents which we have here supposed to be the causes of the solar diurnal magnetic variations. It must not, however, be supposed that in making this suggestion we imply that phenomena of an auroral nature are not likewise connected with magnetic disturbances.

It is to be remarked in conclusion that a system of atmospheric currents will act inductively on the terrestrial magnetic system, so that the final effect on the needle will be the conjoint effect of the currents above and of the magnetic change below. In the case of the declination it is our inability to express the force that acts near the equator or near the magnetic pole in terms of any conceivable general change in the magnetic system that induces us to look to atmospheric currents as affording us a simpler mode of expressing observed facts. This, however, does not hold for the horizontal force near the equator. A set of currents moving east in both hemispheres will produce by induction a definite and well-understood effect upon the terrestrial magnetic system. We do not, therefore, know how far the change produced by the sun upon this element is due to a cause above the needle or how much to magnetic change below; and in this respect the conclusions we have deduced may require modification.

ON THE DIURNAL PERIOD OF TERRESTRIAL MAGNETISM [1]

THE explanation of the daily variation of the magnetic forces observed on the surface of the earth will, in all probability, lead to the explanation of the mysterious connection between solar phenomena and terrestrial magnetism. For the increase in amplitude of the diurnal variation of the horizontal components of magnetic force forms one of the most striking effects accompanying the increase in sunspot activity. The daily variation, then, seems a most important symptom of solar ininfluence, and its investigation becomes a matter of great interest.

In the remarks which I wrote out for the Report of the Committee appointed by the British Association for the purpose of considering the best means of comparing and reducing magnetic observations, I pointed out the importance of adopting a suggestion, made already by Gauss, to apply the analysis of surface harmonics to the diurnal oscillations. It is well known that such an analysis would allow us to decide the question whether the immediate cause of the disturbance was inside or outside the surface of the earth; nor can there be two opinions as to the importance of definitely settling that question. At the time I wrote out my suggestions, however, it seemed to me that, as the causes of the disturbance had their seat in all probability close to the surface, whether outside or inside, that we should require a large number of terms in the expansion before we could arrive at a definite result.

In this I was mistaken, and it is one of the principal objects of this paper to show that the periodic variations adapt themselves with great facility to the analysis, and that even with the very limited quantity of material at our disposal we shall be able to arrive at most important results; results which within a short time might be made absolutely certain if additional observations at a few well-selected stations are taken. My results, as far as they go, point definitely to the region *outside the surface of the earth* as the locality of the periodic cause of the variation. It is easy to see that, if electric currents parallel to the earth's surface produce any disturbance, we can readily find out whether these currents are outside or inside the earth. As we pass through any current-sheet, the normal magnetic force remains continuous, but that tangential component which is at right angles to the current suffers a discontinuity depending on the intensity of the current. For a spherical current-sheet these components will always be of opposite sign. If we then find the distribution of magnetic potential on the surface of the earth from the horizontal components only, we should get by calculation a vertical component of different sign according as the cause is inside or outside. A comparison with the observed values will at once decide the question. A more careful analysis is necessary, if the causes are partly outside and partly inside, and we wish to determine their relative importance.

I believe that few practical magneticians at the present day read Gauss's memoir "On the General Theory of Terrestrial Magnetism," and the loss which cosmical physics has suffered in consequence is, as far as our generation is concerned, quite irretrievable. The memoir is a model of scientific reasoning, and full of suggestions which are as valuable now as they were fifty years ago. The investigations of Gauss are founded on the assumption of a magnetic potential on the surface of the earth, but that assumption requires justification in the case of magnetic disturbances. There will be no potential if there is a discharge of electricity through the earth's surface, and a variation of electric charge would be equivalent to a current. Calculation shows that electrostatic experiments on the surface of the earth would have shown before now if there was a sufficiently rapid change in electric potential to cause a disturbance of the magnetic needle. As regards an actual discharge, it is difficult to form an estimate, and we have therefore to fall back on magnetical observations, and see whether or not they seem to show that the line-integral of magnetic force taken round a closed curve vanishes. The calculations of the author, made on the assumption that it does vanish, seem to show a general agreement with fact; but some observations of Sabine, taken near the magnetic pole, would, if confirmed, point to a discharge in the Arctic regions.

The determinations of the diurnal variation of the magnetic variations show such a remarkable regularity everywhere except in the Arctic regions, and especially in latitudes between 20° and 60°, that we may as a first approximation express the westerly force (measured as change in declination) as the product of two quantities, one changing with local time, the other with latitude only. This assumption leads to the conclusion that the northerly component of force ought to be a maximum or minimum when the declination-needle passes through its mean position. This is very nearly true at Greenwich, Bombay, Lisbon, and Hobart. The agreement is not quite so good at the Cape of Good Hope and in St. Helena, but the observations at these places show some marked anomalies. It is found by observation that the variation in declination increases with the latitude, and we may as a first approximation put it proportional to the sine of the latitude. Writing γ for the westerly, χ for the northerly component of force, u for the co-latitude, λ for the longitude reckoned towards the east, and t for the local time, we may put

$$\gamma = \cos u \cos (t + \lambda).$$

It follows from this, on the assumption of the existence of a potential, that

$$\chi = \cos 2u \sin (t + \lambda).$$

The important point here is the factor $\cos 2u$, which changes sign at a latitude of 45°. If our equation is approximately right, the northerly force ought to be a maximum in the morning, a minimum in the afternoon in the equatorial regions where $\cos 2u$ is negative, while in latitudes above 45° the minimum ought to take place in the morning. This is exactly what happens, with the exception that the change seems to take place in latitudes smaller than 45°. At Bombay the *maximum* of horizontal force takes place at 11 o'clock a.m. At Greenwich the *minimum* takes place a little after that time.

At Lisbon ($u = 51°$) the phase agrees in summer with Greenwich, and in winter with Bombay, the Greenwich type pre-

[1] Abstract of a Paper read before the Manchester Literary and Philosophical Society, by Arthur Schuster, F.R.S.